VARIABLE OUTPUT CREST FACTOR ELECTROSURGICAL GENERATOR

CROSS REFERENCE TO RELATED APPLICATIONS:

This application claims the benefit of priority to U.S. Provisional Application Serial No. 60/432,391 filed on December 10, 2002 the entire contents of which are hereby incorporated by reference herein.

BACKGROUND

1. Technical Field

The present disclosure is directed to electrosurgery and, in particular, to an electrosurgical generator capable of controlling its output crest factor, as well as the output power, across a range of tissue impedances during electrosurgery.

2. Description of the Related Art

Tissue heating is proportional to the square of the amount of current being generated through the tissue and tissue vaporization is, in turn, generally proportional to current. Vaporization of tissue is proportional to the amount of energy in an arc. This energy in combination with the Cathode Fall Voltage, derives the power of vaporization. Thermal spread is dependent on the amount of heat generated within the tissue which is dependent on tissue resistivity and the arc

energy squared. As can be appreciated, by not controlling the thermal spread the depth of ablation is difficult to predict and control.

Therefore, during electrosurgery, an increase or decrease in the amount of current provides a different tissue effect. This phenomenon is due to a variable referred to as the crest factor (CF). The crest factor can be calculated using the formula: $CF=V_{PEAK}/V_{RMS}$, where V_{PEAK} is the positive peak of the waveform and V_{RMS} is the RMS value of the waveform. The crest factor can also be calculated using the formula: $CF=[(1-D)/D]^{1/2}$, where D is the duty cycle of the waveform and is defined as $D=T_1 / (T_1 + T_2)$.

Based on the above formulas, it is evident that when operating an electrosurgical generator in either the "cut", "blend" or "coagulate" mode, the range of the crest factor varies from one mode to another. For example, the "cutting" mode typically entails generating an uninterrupted sinusoidal waveform in the frequency range of 100kHz to 4MHz with a crest factor in the range of 1.4 to 2.0. The "blend" mode typically entails generating an uninterrupted cut waveform with a duty cycle in the range of 25% to 75% and a crest factor in the range of 2.0 to 5.0. The "coagulate" mode typically entails generating an uninterrupted waveform with a duty cycle of approximately 10% or less and a crest factor in the range of 5.0 to 12.0. For the purposes herein, "coagulation" is defined as a process of desiccating tissue wherein the tissue cells are ruptured and dried. "Vessel sealing" is defined as the process of liquefying the collagen in the tissue so that it reforms into a fused mass with significantly-reduced demarcation between the opposing tissue structures (opposing walls of the lumen). Coagulation of small vessels is usually sufficient to

permanently close them. Larger vessels need to be sealed to assure permanent closure.

An increase in the crest factor results in more current per arc at a given power setting. Further, since tissue heating is proportional to the amount of current through the tissue squared and tissue vaporization is proportional to the amount of current being generated through the tissue, a doubling of current per arc results in four times as much tissue heating and twice the amount of tissue vaporization. Known electrosurgical generators do not control the crest factor of the electrosurgical output current. Such electrosurgical generators produce the same crest factor waveform across a range of tissue impedance. Some electrosurgical generators reduce or otherwise change the output power to achieve a surgical effect. However, no known electrosurgical generators alter both the output crest factor and output power across a range of tissue impedance to achieve a particular surgical effect. Accordingly, such electrosurgical generators do not have the ability to manipulate or control the proportion of tissue vaporization to tissue heating, in order to achieve more controllable and desirable surgical effects.

Therefore, it is an aspect of the present disclosure to provide an electrosurgical generator capable of regulating the output crest factor of the electrosurgical generator, as well as the output power, across a range of tissue impedance for controlling both tissue heating and tissue vaporization.

SUMMARY

An electrosurgical generator is disclosed capable of controlling its output crest factor, as well as the output power, across a range of tissue impedance during electrosurgery. The control occurs in real time during an electrosurgical procedure by the electrosurgical generator varying both the output crest factor and output power based on the changing impedance of the tissue.

The electrosurgical generator determines whether to vary the output crest factor and output power by monitoring the output voltage and output current. By monitoring the output voltage and output current, the electrosurgical generator, using programmable instructions executed by at least one processor, is able to determine the tissue impedance.

If the determined tissue impedance is low, the present value of the crest factor is low, and if the determined tissue impedance is high, the present value of the crest factor is high. According to the type of surgical procedure being performed, the electrosurgical generator then automatically adjusts or maintains the values of the output crest factor and the output power. The value of the output crest factor is preferably adjusted by varying the duty cycle of the generated waveform, the positive peak and/or RMS value of the generated waveform.

The electrosurgical generator also includes controls for allowing a surgeon to select the appropriate crest factor value and output power value for a particular surgical procedure. Hence, the output crest factor and output power can

be manually adjusted by the inventive electrosurgical generator. Therefore, by automatically adjusting the output crest factor and by giving the surgeon the ability to manually "tailor" the output crest factor across a range of tissue impedance, the inventive electrosurgical generator allows for a greater range of surgical effect and desirable surgical results.

In brief, the electrosurgical generator of the present disclosure is capable of varying both the output crest factor and output power based on the changing impedance of tissue during electrosurgery. The electrosurgical generator includes a processing unit for receiving at least one signal indicative of an output voltage and an output current. The processing unit executes a set of programmable instructions for determining the tissue impedance using the output voltage and output current. The processing unit then transmits a waveform adjustment signal to a waveform generator which adjusts the output crest factor and output power based on the determined tissue impedance.

The method of the present disclosure varies both the output crest factor and output power of an electrosurgical generator based on the changing impedance of tissue during electrosurgery. The method includes the steps of determining tissue impedance using an output voltage and an output current of the electrosurgical generator. The method then includes the step of adjusting the output crest factor and output power of the electrosurgical generator based on the determined tissue impedance.

The present disclosure also provides a power source for generating an output voltage and an output current for an electrosurgical generator system which is capable of varying both the output crest factor and output power based on the changing impedance of tissue during electrosurgery. The electrosurgical system includes a processing unit for receiving at least one signal indicative of the output voltage and the output current. The processing unit executes a set of programmable instructions for determining the tissue impedance using the output voltage and output current and transmitting at least one waveform adjustment signal. The waveform adjustment signal is received by a waveform generator of the electrosurgical generator system for adjusting the output crest factor and output power based on the determined tissue impedance.

Further features of the above embodiments will become more readily apparent to those skilled in the art from the following detailed description of the apparatus taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments will be described herein below with reference to the drawings wherein:

FIG. 1 is a schematic diagram of an electrosurgical generator in accordance with one embodiment; and

FIG. 2 is a flowchart illustrating a method of operation of the electrosurgical generator in accordance with the present disclosure.

DETAILED DESCRIPTION

Reference should be made to the drawings where like reference numerals refer to similar elements. Referring to FIG. 1, there is shown a schematic diagram of one embodiment of the present electrosurgical generator. The electrosurgical generator is designated generally by reference numeral 100 and it includes a processor 102 for receiving voltage and current output signals, V_{out} and I_{out}, for monitoring the output voltage and output current, respectively. Using the signals V_{out} and I_{out}, the processor 102 calculates the tissue impedance using a set of programmable instructions.

After calculating the tissue impedance, the processor 102 accesses at least one look-up table or other data structure to determine an appropriate output crest factor value and output power value for the calculated tissue impedance. The look-up table or other data structure is stored within a memory module of the processor 102 or, alternatively, within an external memory. (Not shown.) After determining the proper output crest factor value and output power value for the calculated tissue impedance, the processor 102 determines whether to adjust the output crest factor and/or the output power to predetermined values, i.e., the values provided by the look-up table.

The processor 102 adjusts the output crest factor by sending a signal CF_{adjust} to a waveform generator 104 to alter the duty cycle of the generated waveform or waveform signal. By altering the duty cycle of the generated waveform,

the output crest factor is adjusted in accordance with the following formula: $CF=[(1-D)/D]^{1/2}$, where D is the duty cycle of the waveform and is defined as $D=T_1 / (T_1 + T_2)$.

The processor 102 can also adjust the output crest factor by sending a signal WF_{adjust} to the waveform generator 104 to alter the positive peak and/or RMS value of the generated waveform in accordance with the following formula: $CF=V_{PEAK}/V_{RMS}$, where V_{PEAK} is the positive peak of the waveform and V_{RMS} is the RMS value of the waveform. The two signals CF_{adjust} and WF_{adjust} may be generated and sent by the processor 102 to the waveform generator 104 simultaneously or sequentially as determined by a set of programmable instructions executed by the processor 102.

Preferably, the processor 102 determines which of the parameters to alter, i.e., the duty cycle, the positive peak of the generated waveform and/or the RMS value of the generated waveform according to which parameter change would provide the most desirable and/or particular surgical result. Hence, the processor 102 takes into consideration which surgical procedure is being performed, (i.e., which operational mode is currently activated on the electrosurgical generator 100-cut, coagulate, blend or seal) prior to altering the output crest factor. The processor 102 adjusts the output power by adjusting the output voltage V_{out} and/or output current I_{out} as known in the art.

The adjustment of the output crest factor and output power as described above occurs automatically, in real time and continuously for the duration of the surgical procedure. That is, during the activation of the electrosurgical

generator 100, it is envisioned that the electrosurgical generator 100 can vary the output crest factor, output power output and/or the waveform based on the changing impedance of the tissue as determined by continuously monitoring the output voltage V_{out} and output current I_{out}.

FIG. 2 shows a flow chart illustrating a method for controlling the electrosurgical generator 100 in accordance with the present disclosure. In step 210, the method includes monitoring the output voltage V_{out} and output current I_{out} of the electrosurgical generator 100. In step 220, the tissue impedance is determined using the monitored output voltage and output current. In step 230, the output crest factor and output power of the electrosurgical generator are adjusted based on the determined tissue impedance.

A surgeon may override the method described above and illustrated by the flow chart of FIG. 2 by selectively adjusting controls 106 on the electrosurgical generator 100 to a particular output crest factor value and/or output power value for achieving a particular surgical effect. By adjusting the controls 106, the processor 102 sends a signal to the waveform generator 104 to alter the duty cycle of the generated waveform, or other parameter, such that the output crest factor is approximately equal to the output crest factor selected by the surgeon.

The controls 106 afford the surgeon the opportunity to manually "tailor" the mode for the surgical procedure. For example, during the "cut" operational mode, the processor 102 using the set of programmable instructions would adjust the output crest factor to be within the range of 1.4 to 2.0. However, the surgeon

may determine that the type of tissue being cut requires the generated waveform to have an output crest factor value of 1.1 or less. Hence, the surgeon can override the automatic and real time adjustment of the output crest factor value by manually setting the output crest factor value to 1.1 using the controls 106. In addition, the surgeon may wish to control the power for other reasons, e.g., limit the thermal spread to surrounding tissue. Examples and benefits to controlling the power are explained in detail in commonly-assigned U.S. Patent No. 6,228,080, the entire contents of which are hereby incorporated by reference herein.

It is contemplated that the electrosurgical generator 100 can be designed to determine the tissue impedance and adjust the output crest factor and the output power accordingly by utilizing circuitry and other hardware, rather than using programmable instructions executed by the processor 102.

Accordingly, the present disclosure provides an electrosurgical generator 100 which is capable of controlling both the output crest factor and output power across a range of tissue impedance during electrosurgery.

Although this disclosure has been described with respect to preferred embodiments, it will be readily apparent to those having ordinary skill in the art to which it appertains that changes and modifications may be made thereto without departing from the spirit or scope of the disclosure.